

RECENT RESULTS FROM THE HDMS EXPERIMENT

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The status of dark matter search with the HDMS experiment is reviewed. After one year of running the HDMS prototype detector in the Gran Sasso Underground Laboratory, the inner crystal of the detector has been replaced with a HPGe crystal of enriched ^{73}Ge . The results of the operation of the HDMS prototype detector are discussed.

The Heidelberg Dark Matter Search (HDMS) Experiment is designed to look for Weakly Interacting Dark Matter Particles (WIMPs). Through a special configuration an effective background reduction is achieved with respect to a conventional design, which results in an increase of sensitivity for WIMP Dark Matter.

Here we present first results of the Heidelberg Dark Matter Search (HDMS) experiment ^{1,2}, whose prototype took data over a period of about 15 months in the Gran Sasso Underground Laboratory at LNGS in Italy. The last 49 days of data taking are analyzed in terms of WIMP-nucleon cross sections and a comparison to other running dark matter experiments is made. The final experiment operating an enriched ^{73}Ge crystal inside a natural Germanium detector has been installed in august 2000.

1 The HDMS experiment

HDMS operates two ionization HPGe detectors in a unique configuration ^{1,2}. A small, p-type Ge crystal is surrounded by a well-type Ge crystal, both being mounted into a common cryostat system (see Figure 1 for a schematic view). Two effects are expected to reduce the background of the inner target detector with respect to our best measurements with the Heidelberg-Moscow experiment ³. First, the anticoincidence between the two detectors acts as an effective suppression of multiple scattered photons. Second, we know that the main radioactive background of Ge detectors comes from materials situated in the immediate vicinity of the crystals. In the case of HDMS the inner detector is surrounded (apart from the thin isolation) by a second Ge crystal - one of the radio-purest known materials.

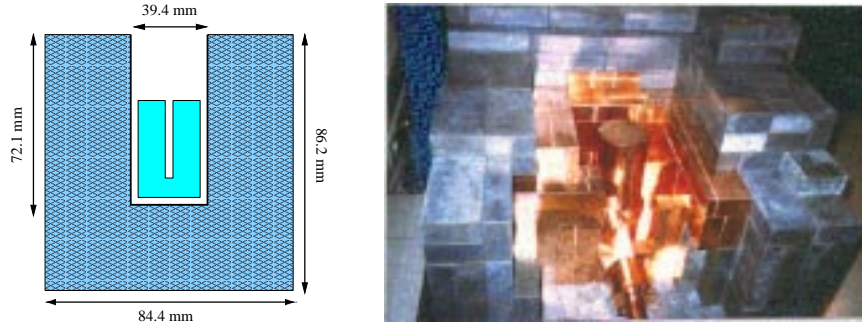


Figure 1. Left: Schematic view of the HDMS experiment. A small Ge crystal is surrounded by a well type Ge-crystal, the anti-coincidence between them is used to suppress background created by external photons. Right: The HDMS prototype detector during its installation at LNGS.

In order to house both Ge crystals and to establish the two high-voltage and two signal contacts, a special design of the copper crystal holder system was required. The cryostat system was built in Heidelberg and made of low radioactivity copper, all surfaces being electro-polished. The FETs are placed 20 cm away from the crystals, their effect on the background is minimized by a small solid angle for viewing the crystals and by 10 cm of copper shield.

1.1 Detector Performance at LNGS

The HDMS prototype was installed at LNGS in March 1998. Figure 1 shows the detector in its open shield. The inner shield is made of 10 cm of electrolytic copper, the outer one of 20 cm of Boliden lead. The whole setup is enclosed in an air tight steel box and flushed with gaseous nitrogen in order to suppress radon diffusion from the environment. Finally a 15 cm thick borated polyethylene shield surrounds the steel box in order to minimize the influence of neutrons from the natural radioactivity and muon produced neutrons in the Gran Sasso rock.

The prototype detector successfully took data over a period of about 15 months, until July 1999. The individual runs were about 0.9 d long. Each day the experiment was checked and parameters like leakage current of the detectors, nitrogen flux, overall trigger rate and count rate of each detector were checked. The experiment was calibrated weekly with a ^{133}Ba and a ^{152}Eu - ^{228}Th source. The energy resolution of both detectors (1.2 keV at 300 keV inner detector and 3.2 keV at 300 keV outer detector) were stable as a func-

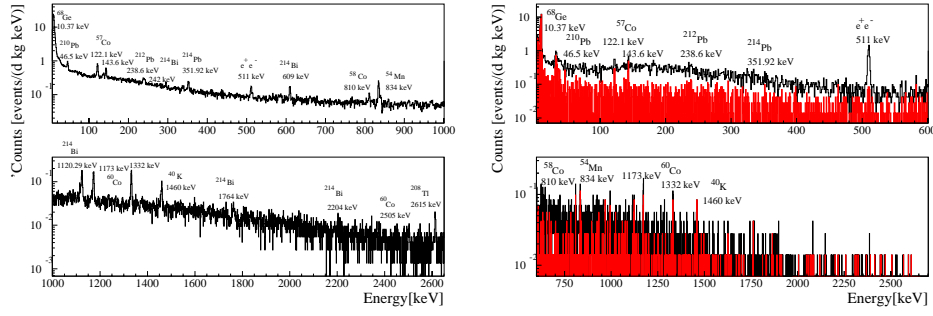


Figure 2. Left: Sum spectrum of the outer detector after a measuring time of 363 days. The most prominent lines are labeled. Right: Sum spectrum of the inner detector after a measuring time of 363 days. The most prominent lines are labeled. The filled histogram is the spectrum after the anti-coincidence with the outer detector.

tion of time. The zero energy resolution is 0.94 keV for the inner detector and 3.3 keV for the outer one.

The energy thresholds are 2.0 keV and 7.5 keV for the inner and outer detector, respectively.

Due to the very special detector design, we see a cross-talk between the two detectors. The observed correlation is linear and can be corrected for off-line ⁴. After correction for the cross talk and recalibration to standard calibration values, the spectra of the daily runs were summed. Figure 2 shows the sum spectra for the outer and inner detector, respectively (the most important identified lines are labeled).

In the outer detector lines of some cosmogenic and anthropogenic isotopes, the U/Th natural decay chains and ⁴⁰K are clearly identified. The statistics in the inner detector is not as good, however the X-ray at 10.37 keV resulting from the decay of ⁶⁸Ge, some other cosmogenic isotopes, ²¹⁰Pb and ⁴⁰K can be seen. The region below 10 keV is dominated by the X-rays from cosmogenic radio nuclides. In addition a structure centered at 32 keV is identified. Its origin is not yet clear and is currently under investigation.

After 363 days of pure measuring time the statistics in the inner detector was high enough in order to estimate the background reduction through the anti-coincidence with the outer detector.

Figure 3 shows the low-energy spectrum of the inner detector before and after the anti-coincidence. The cosmogenic X-rays below 11 keV are preserved, since in this case the decays are occurring in the inner detector

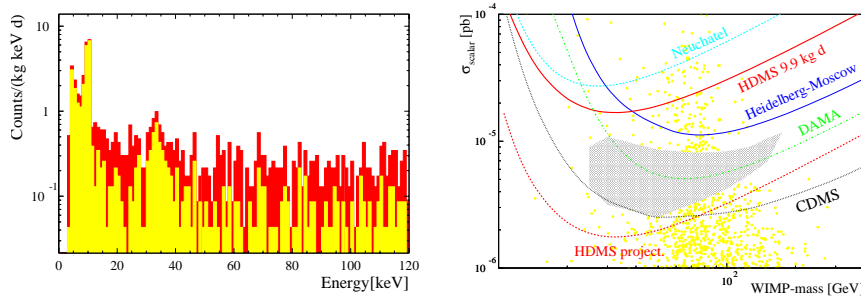


Figure 3. Left: Low energy spectrum of the inner detector. The light shaded spectrum corresponds to the events using the anticoincidence, the dark shaded spectrum to all events. Right: WIMP-nucleon cross section limits as a function of the WIMP mass for spin-independent interactions. The solid line corresponds to the limit set by the HDMS-prototype detector. The other plain curves correspond to the limits given by CDMS ⁵, DAMA ⁶ and the Heidelberg-Moscow Experiment ³. The filled contour represents the 2σ evidence region of the DAMA experiment ⁷. The dashed line corresponds to the expectation for the final HDMS detector, assuming a threshold of 2 keV.

itself. The same is valid for the structure at 32 keV, also a ^3H spectrum with endpoint at 18.6 keV is presumably present. If the anti-coincidence is evaluated in the energy region between 40 keV and 100 keV, the background reduction factor is 4.3. The counting rate after the anti-coincidence in this energy region is 0.07 events/(kg d keV), thus very close to the value measured in the Heidelberg-Moscow experiment with the enriched detector ANG2 ³. In the energy region between 11 keV and 40 keV the background index is with 0.2 events/(kg d keV) a factor of 3 higher.

1.2 Dark Matter Limits

The evaluation for dark matter limits on the WIMP-nucleon cross section $\sigma_{\text{scalar}}^{\text{W-N}}$ follows the conservative assumption that the whole experimental spectrum consists of WIMP events. Consequently, excess events from calculated WIMP spectra above the experimental spectrum in any energy region with a minimum width of the energy resolution of the detector are forbidden (to a given confidence limit).

The parameters used in the calculation of expected WIMP spectra are summarized in ³. We use formulas given in the extensive review ⁸ for a truncated Maxwell velocity distribution in an isothermal WIMP-halo model (truncation at the escape velocity, compare also ⁹).

After calculating the WIMP spectrum for a given WIMP mass, the scalar cross section is the only free parameter which is then used to fit the expected to the measured spectrum using a one-parameter maximum-likelihood fit algorithm.

To compute the limit for the HDMS inner detector we took only the last 49 days of measurement. We omit the first 260 days in order to reduce the contaminations due to long-lived cosmogenically produced materials. These have life times of typically ~ 200 days. The energy threshold of the measurement was 2 keV. The resulting preliminary upper limit exclusion plot in the $\sigma_{\text{scalar}}^{\text{W-N}}$ versus M_{WIMP} plane is shown in Fig. 3.

Already at this stage, the limit is competitive with our limit from the Heidelberg-Moscow experiment. In the low mass regime for WIMPs the limit has been improved due to the low energy threshold of 2 keV reached in this setup.

Also shown in the figure are limits from the Heidelberg-Moscow experiment ³, limits from the DAMA experiment ⁶ and the most recent results in form of an exclusion curve from the CDMS experiment ⁵. The filled contour represents the 2σ evidence region of the DAMA experiment ⁷.

1.3 Outlook for the HDMS Experiment and conclusions

The prototype detector of the HDMS experiment successfully took data at LNGS over a period of about 15 months. Most of the background sources (with exception of the 32 keV structure in the inner detector) were identified. The background reduction factor in the inner detector through anticoincidence is about 4. The background in the low-energy region of the inner detector (with exception of the region still dominated by cosmogenic activities) is already comparable to the most sensitive dark matter search experiments.

For the final experimental setup, important changes were made. The crystal holder was replaced by a holder made of ultra low level copper, the soldering of the contacts was avoided, thus no soldering tin was used in the new setup and finally the inner crystal made of natural Germanium in the described prototype was replaced by an enriched ^{73}Ge crystal. In this way, the ^{70}Ge isotope (which is the mother isotope for ^{68}Ge production) is strongly de-enriched (the abundance in natural Germanium is 7.8%).

After a period of test measurements in the low-level laboratory in Heidelberg, the full scale experiment was installed at LNGS in August 2000. The energy threshold of the inner detector is unchanged at 2.0 keV and the energy resolution has slightly improved with respect to the prototype detector ¹⁰.

The projected final sensitivity of the detector can be seen in Fig. 3.

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